ON THE "PROGRESS OF ARCHITECTURE IN RELATION TO VENTILATION, WARMING, LIGHTING, FIRE-PROOFING, ACOUSTICS, AND THE GENERAL PRESERVATION OF HEALTH."

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FIRST LECTURE.

Professor Henry introduced Dr. Reid to the audience, and, in adverting to his plans for ventilation, quoted an extract from some recent proceedings of the Royal Institution in London, where Dr. Bence Jones had given certain statistical details showing the great reduction of mortality in an hospital which Dr. Reid had ventilated, and that the mortality increased again when the ventilation was suspended.

After responding to the remarks of Professor Henry, Dr. Reid claimed the indulgence of the audience in entering on a course while still imperfectly acquainted with this country, and perhaps not yet fully acclimated to it, as the experience of personal illness for the last fort-night had taught him.

Dr. Reid then commenced his first lecture with a general sketch of the position in which man is placed on this globe. With his natural wants at first supplied in a congenial climate, he was still, at a very early period of history, like a traveller without a guide in respect to many departments of *physique*, except those external senses which an omnipotent creator had given him wherewith to steer his course in the material world. Increase of knowledge, arts, and manufactures gradually accompanied an increasing population. New climates, new wants, and new occupations stimulated his ingenuity and rewarded his invention as much as it increased his comforts. Dwellings in caves or clefts of rocks, such as are described in the Sacred Scriptures, as well as tents and huts, the primitive abodes of man, soon gave way in many places to more systematic habitations, though these are still to be found away from the scenes of civilization. Monuments and public temples then arose in Cyclopean, Egyptian, Druidical, Indian, Chinese, and Mexican architecture. The Greeks, with the finest eye for beauty and proportion, excelled all their predecessors; the Romans added a gorgeousness and luxuriance of ornament that competed with, without rivalling, the severe and more scrupulous taste of Grecian architecture; and then followed a host of styles that have multiplied indefinitely, in which the spire and the dome, the pointed and the circular arch are continued with endless modification, to the crystal palace and iron buildings of modern times.

But during all this period comparatively little attention was paid to the question of air, which has been so much the subject of later investigation. Buildings were at first too imperfect in their structure and fittings to form those air-tight receptacles that have multiplied so largely in our day. The same resources and machinery were not available for their construction. The habits and occupations of the people were different. Few read, and still fewer wrote, till the press began to diffuse its influence among mankind. The illumination of rooms at night with an artificial daylight by means of gas is but a recent invention.

But with all these inventions the duration of human life has not increased, except in local and special instances. Passing over the times of the ancient patriarchs, human life seems still, on the whole, to have been diminishing from the time when it is generally supposed to have been reduced to threescore and ten. How many places are there where from a quarter to a half of the population now die within from five to ten years; born, as it were, to pass through an infancy of suffering and sorrow, and then to disappear from this transitory scene. And then, if we look to adults, is it not true that many, so far from attaining threescore and ten, are cut off before they are twenty-five? An age of fifty years is beyond the average, and threescore and ten, or upwards, is still more rarely attained. But is there any just foundation for the belief that threescore and ten is the allotted period for man's existence? Is the passage from the Psalms correctly interpreted to which this alleged maxim is usually ascribed? He contended that it was not; that Biblical critics usually attributed this psalm to Moses, believing that it was written by him in the wilderness, when the Israelites were exposed to great suffering, and as yet he had met with no clergyman of any denomination who was disposed to insist on the popular interpretation usually ascribed to it. He thought the subject one of great practical importance; that the question should be set on a right footing; that if it were not only possible, but probable, that a marked extension of five, ten, fifteen, or five-and-twenty years could be given to human life by attention to the moral, religious, and physical elements that entered into it, nothing would contribute more to place the whole subject of the care of health, the increase of comfort, and the prevention of disease on a better footing. It would regulate, or at least affect, the period of infancy and education, the time of entering on business, and form an element in all subsequent concerns of life. Above all, it would be one of the strongest checks upon that system of fast living and that incessant strain upon the nervous system that was so marked in thousands and tens of thousands of cases, especially in populous cities, whether we looked to London or Paris, to New York or St. Petersburgh. Vain would the attempt be to extend the duration of man's life if the nervous system was exhausted, whether from an honorable ambition, an imperious necessity, a corrupt luxury, or a want of faith, hope, and contentment in the providence of the Creator.

Dr. Reid then turned his discourse to the physical evils attendant on human life, and explained the magnitude of that resulting from defective ventilation. Man respired, on an average, twelve hundred times an hour during the whole period of his existence. The lungs contained millions of cells, and if pure air were not supplied all these provisions for life and health were more or less useless; the blood became changed in its qualities; the brain, the eye, the ear, and every tissue and fibre of the human frame were more or less affected. The result varied in every degree—from the most trifling headache, listlessness, or langor, to every variety of fever, scrofula, consumption, or even, in extreme cases, to sudden and immediate death.

In large cities and in all populous districts a proper system of drainage and external cleansing were the true remedy for periodical evils too often attributed to wrong causes. These being secured, the right ingress and egress of air in individual buildings and habitations became the next desideratum.

Few cities, comparatively, large or small, were cleaned to the extent necessary for the right preservation of health; nor was it to be expected that this subject would receive adequate attention till the united efforts of medical men, engineers, architects, and agriculturists should be brought to bear upon it. Great progress had been made, unquestionably, in recent years; but a more systematic, combined, and harmonious effort was desirable than was in operation, either in this country or in Europe, so far as I have had the opportunity of observing. The medical profession was responsible for pointing out the sources of disease and death, but, without the aid of the agriculturist, it was, in general, found impossible to obtain the funds necessary for effective cleansing; and what could be done in this respect where a good system of engineering did not afford an ample supply of water and the requisite drainage, or where a defective architecture did not provide the proper facilities for the removal of refuse? In London, after the experience of upwards of a thousand years, the authorities had at last become convinced that the condition which the river attains from the drainage thrown into it is an evil of the greatest magnitude, and a reference to the newspapers of the day would show the determination to reduce this evil, though nothing effectual can be done under an expenditure of millions of pounds. Is it not the case, that in this city the continued drainage into the canal may become more and more objectionable every succeeding year, and is there not abundant evidence that a right system of drainage and sewerage, with proper attention to the ventilation of drains, would here lessen disease and suffering? In Paris the whole atmosphere is sometimes tainted with an ammoniacal odor; and who has ever crossed the "Unter den Linden," in Berlin, at least when in the condition in which it was a few years ago, without being admonished of what had still to be done in that city. Modern chemistry has not yet developed and explained all the varieties of malaria, natural and artificial, that interfere with the preservation of a pure atmosphere, but it has most emphatically pointed out many of their sources in innumerable habitations in cities, villages and populous districts, as well as the means of correcting them. It was a self-evident proposition that the first step in all effective ventilation is to start with a good atmosphere; but such was the apathy, indifference, and sometimes the ignorance, on this point that it often became a most troublesome question to deal with in a satisfactory manner, particularly where tracts of ground had become saturated with debris in a perpetual state of putrefactive fermentation, or where streams or stagnant water were loaded with similar materials. In the great theatre of the globe itself, the general purity of the atmosphere was sustained by the mutual relations of the animal, the vegetable, and the mineral kingdom; by the perpetual rotatory currents flowing from the equator toward the poles and from the poles towards the equator; by that great peculiarity in all gases and vapors which constantly led to their diffusion through each other, however different in specific gravity, so that nowhere on the surface of the earth where there was free access to the external atmosphere could any accumulation of any noxious product take place without a process of dissipation and dilution being immediately commenced; and by the chemical action of the air, which was perpetually tending to oxidate or burn all malarious products. But how largely were these natural agencies counteracted, within as well as without doors, when there was a deficiency in the supply of air, or an excess in the material of decomposition. Many were the districts in which a rich and luxuriant vegetation consumed the products that gave rise previously to fever and ague. Travellers have expressed their great surprise at the total absence of these diseases under circumstances where they had anticipated their severe operation, and traced, subsequently, to the action of special plants the conservative influence that guarded them from danger. Let this lesson, said Dr. Reid, not be neglected; let it be applied in full force, and the facts be studied and developed with an untiring assiduity, till miasma shall be largely overcome in all cities subject to its influence, and the water-lilly and other aquatic plants shall have improved the condition of all accumulations of water in their vicinity, as much as an active and vigorous vegetation purifies the air that moves upon the land. If he dwelt more upon this point than might at first appear requisite, it was because its importance, though admitted, was by no means adequately estimated. He did not consider that there was any question connected with the material world that promised greater blessings to large cities and populous districts than those that would flow from professional investigation and practical experience in this department, combined with the information available from former ages, and the practice of different nations. It had been demonstrated that a large proportion of the deaths that filled the annual bills of mortality arose from preventible causes; and in making any estimate on this subject, it ought never to be forgotten that every death indicated many cases of disease and suffering that were never registered in the ordinary tables. How great, then, is the question at issue, and how many and how varied would the channels be through which its right solution would affect society?

Dr. Reid then showed by experiments the fundamental principles of ventilation, illustrating the tendency of the air to assume rotatory movements, and thus induce the removal of vitiated and the supply of fresh air whenever expansion or any other cause produces a disturbance in the atmospheric balance. The effect of the human frame in inducing such currents was then pointed out. The body always ventilates itself if the natural currents it determines are not impeded by the architecture which surrounds it.

A special ventilating shaft has been constructed in this Institution for the illustrations, and a connexion is established between it and a tube and chamber in the experimental table, by which a ventilating power is brought to bear on any visible vapors used in explaining the principles and practice of ventilation.

SECOND LECTURE.

Dr. Reid commenced this lecture with different illustrations of the movement of air. Mechanical means—as pumps, fanners and bellows, or a current of air or water, the action of heat, the impulse of steam, and the repelling power of electricity—had all been employed with the view of moving air; and all these forces had been practically applied in sustaining ventilating operations, with the exception of electricity. This agent, hitherto, had only been used experimentally.

For all ordinary purposes, no power was so generally useful and available for ventilation as that arising from the action of heat on air or other gases. Referring to the ventilating shaft connected with the experimental table at which he lectured, it was shown that a column of heated air in the interior could not balance or resist the pressure of the colder air in the apartment from which it was supplied, air being admitted freely into it from the external atmosphere. It was not strictly accurate to say that heated air ascended, in describing this movement in a technical manner. It was more correct to state that air, when warmed, became expanded, and lost its power of balancing the contiguous air, which then pressed in upon it on every side and forced it upwards. The right understanding of this point was essential in the study of all the more familiar phenomena of ventilation. It was then shown, that on establishing a free communication with the lower portion of the heated shaft, a flexible tube could be made to carry a ventilating power in any direction, and, at the fixtures connected with the table, flame, smoke and various colored vapors were made to move upwards, downwards, laterally, and in other directions, according to the position in which the apparatus used at each was placed, and the amount of power brought to bear upon the materials employed.

The tendency of air, when falling in temperature, to descend to a lower level, was then pointed out. This was illustrated practically by the exhibition of a heavy, cloud-looking vapor, that was poured with facility from vessel to vessel and rolled along the table in a continuous stream, as if it had been an ordinary liquid. It was formed by the action of nitric acid, mercury, and alcohol, and used frequently in giving indications of aerial movements that would otherwise have been invisible. Though the materials that became the principal object of attention in ventilating operations were of great tenuity, it was never to be forgotten that they might, in numerous respects, be treated in the same way as water and other liquids.

The quantity of air desirable for ventilation then came under consideration. For each respiration the actual amount required was small. From twenty to thirty cubic inches were sufficient for this purpose; but the expired air contaminates immediately a much larger amount of the surrounding atmosphere. At the same time the surface of the body is continually exhaling vitiated air in the same manner as the lungs. Further, almost all kinds of clothing soon become more or less charged with animal exhalations, and require some addition to the ordinary supply, particularly if dyed with certain chemicals and exposed where they may have imbibed moisture. It is also equally important to notice that every variety of temperature, electrical condition, and humidity in the atmosphere produces a corresponding influence on the sensations as affected by the amount of air brought in contact with the body in a given time. Further, not only are there great varieties of constitution in different individuals, but even in the same person. Before and after dinner or any other refreshment, before and after exercise, and under many other circumstances, very different quantities of air become agreeable or disagreeable, and refreshing or oppressive. Lastly, minute and variable portions of impurity from smoke and manufactories, or from terrestrial exhalations, often modify the amount of supply that is desirable for all constitutions.

It will not be surprising, accordingly, that there is perhaps nothing in respect to which there is a greater difference of practice than in the amount of air given for ventilation, even where we assume that its effect is not still further modified by its mode of introduction and discharge, and the efficiency with which it has the opportunity of acting in passing through the apartment to be ventilated.

It is surprising with how small a proportion of air existence can be maintained for a long period when the system is comparatively inactive. Dr. Reid then described an experiment, in which he had been hermetically inclosed in a case that was not broader than his shoulders, deeper than his chest, or longer than himself; and stated that he had continued there for upwards of an hour, the attendants being ordered to take him out whenever he ceased to answer questions or to give distinct replies. During the whole of that period he had not been particularly incommoded, after getting over a feeling of oppression that attended his first respirations. Apprehensive, however, of some subsequent injurious effects when the oppression he expected did not increase so rapidly as he had anticipated, he directed the case to be undone before any indications were given such as would have led his assistants to have anticipated this order. Nor did he suffer so much as he had expected from the effect subsequently, though headache and restlessness continued for some days to a degree that prevented him from renewing his observations to the extent he had desired.

This experiment was important in corroborating the fact that life might often be sustained for long periods, even in limited quantities of air, where animation was not temporarily suspended.

On the other hand, at different times and under other circumstances, he had suffered more from air not nearly so much contaminated as it was in this instance, and adverted particularly to the fact that the intensity of vitality was often very different in different individuals, and also in one and the same individual at different times. To impress this upon the attention of the audience, an experiment was then shown, in which a common candle, a wax candle, an oil lamp, a spirit lamp, and a gas lamp, were kindled at the same level under a large glass shade, all communication with the external atmosphere having been cut off. In a short time the air became so vitiated that the common candle ceased to burn. Subsequently the wax candle was extinguished, then the oil lamp; the spirit lamp came next in order, and last of all, but long after the others had ceased to burn, the gas lamp was also extinguished, struggling previously in the form of a long pale-blue flame. In the same manner death took place among different individuals, even from the very same causes, in very different periods of time, some sinking without a murmur where the bystanders scarcely noticed the causes that deprived them of life, while others sustained themselves throughout a long and painful struggle.

Dr. Reid then described the manner in which experiments on respiration had been made with small quantities of air, and the peculiarities of the apartments constructed at his lecture room at Edinburgh for researches on respiration and ventilation, where the amount of air supplied to numbers, varying from one to two hundred and fifty, could be precisely ascertained and controlled. Sometimes one or more individuals were placed in an air-tight box, containing a definite amount of air. On other occasions one hundred individuals or upwards were placed in an air-tight room with a porous floor and a porous ceiling, the cavities below and above communicating with channels by which air could be made to enter and be withdrawn in any required proportion.

From these experiments and others the conclusion was drawn that ten cubic feet per minute is an ample allowance of air for an adult—far more than he generally has in ordinary habitations, but not more than every ordinary structure should have the means of providing at a minimum. Dr. Reid was prepared to admit that a less amount would generally sustain health, but asserted that it would not give the comfort and maintain the constitution in such good condition as a larger allowance. In extreme atmospheres, loaded with moisture or charged with special impurities or malaria, and at comparatively elevated temperatures, there was no limit to the amount of increase that proved grateful to particular constitutions. He had, in some cases, given forty, fifty, and even a larger number of cubic feet per minute with advantage, but there the velocity of the air acted essentially as a cooling power from the great amount brought to affect the body in a given time. Such velocity was not desirable where an equivalent effect could be produced by cooling the air previously. But in looking to this question as one that had to regulate practice in construction and the appliances used in connexion with ventilation, he was satisfied that ten cubic feet per minute for each person would be amply sufficient, wherever it was possible to control the temperature and the hygrometric condition of the air to be used.

The practice of merely determining the amount of cubic or superficial space to be given for each soldier in a barrack, each patient in a hospital, or every criminal in a prison, and leaving every other question or means of ventilation to accident, had never been satisfactory, and was now abandoned in all the best buildings for these and other purposes. No dependence whatever can be placed on such a provision beyond the actual amount of pure air they may contain before occupation. The true question is, to determine the amount of pure air that can be made to pass through wards, cells, or any other spaces in a given time, with a maximum of the ventilating power in action, valves or other arrangements reducing the effect to any desirable standard.

In cases with systematic ventilation properly applied, a man in a room densely crowded may have more air than one in a confined area with ten times as much space for his own occupation. Rooms in different habitations vary as much in the amount required at different times and seasons as many public buildings. Further, there is nothing more deceptive to those who have not studied the subject practically than the numbers of persons that can stand on a given space. In special trials, made with the view of determining the numbers that can be accommodated on a floor of known size, several cells were selected at the prisons at Perth, in Scotland, and able-bodied men (engaged at that time in completing the building of the works) were requested to stand in them as close as they conveniently could. Seventy were then counted in one cell having a floor of seventy-two feet, and ninety in another having a floor of ninety-two feet. He had repeatedly seen at the bar of the House of Peers, in London, and in many other places an individual standing upon each area of one foot. When the body of the late Duke of Wellington lay in state at Chelsea hospital, previous to the funeral, he had seen a more dense crowd than he had ever witnessed on any previous occasion. Many were literally crushed to death in this crowd, and numbers who escaped death had the appearance of persons who had fallen into a stream of water and been thoroughly drenched. The morning was cold, calm, and gloomy, such as would have suited the description many foreigners give of a London atmosphere at that period. There was no fog, however, though a small cloud of vapor hung heavily over the densest part of the crowd. It should be remembered, then, that in cases of great interest, all rooms, public and private, are liable, generally or locally, to have like numbers crowded into them, and it becomes, therefore, imperative on those who desire ventilation to state the number to be provided for, rather than the mere area of the floor.

In the chambers for Congress the floor space allotted for individual members was upwards of twice as much as that given at the Houses of Parliament in London, taking into consideration that occupied by the benches or individual seats. This, however, was not an unmixed gain in the House of Representatives at Washington, since the large area of occupation necessarily increased the difficulty of hearing and of seeing the expressions of countenance during the progress of debate.

In explaining the estimate given of the amount of air desirable for ventilation, it was stated that a temperature of sixty-five to seventy would generally be found most acceptable, and a supply of moisture in the air, such as was indicated by a wet-bulb thermometer (the hygrometer in common use) when it showed a temperature five degrees below that of the ordinary thermometer.

The methods of determining the quality of the air in ventilated apartments then engaged attention. None was so pre-eminently available as that of going out of doors where the atmosphere was pure, and then comparing the effect there with that of the apartment under examination. Important as this mode was, it was not, however, sufficiently precise, nor could it always be put practically in operation with convenience while differences of temperature and a want of sensibility in the nostrils, or a loss of the sense of smell from cold, interfered with a correct decision. It was a matter of great practical importance, accordingly, that some accessible and convenient test should be available that would at all times and seasons give an indication that would tell the purity of the atmosphere.

For this purpose Dr. Reid had introduced an instrument called the carbonometer, which was then explained. It admits of a great variety of forms. That shown in action consisted of a bent glass tube attached to a phial containing water, a few drops of lime water being placed in the angle of the bent tube. On taking out the stopple from the phial a portion of the water slowly escaped. This caused a flow of air from the apartment under examination through the lime water, which becomes more or less turbid, according to the amount of carbonic acid in the air. But carbonic acid is invariably present in a very marked proportion in all ordinary atmospheres contaminated by respiration, the combustion of ordinary lamps or candles, or the escape of vitiated air from a fire flue. Any excess beyond that in the atmosphere renders the amount of lime water used slightly opalescent, milky, or turbid and chalky, according to the amount. Forty specimens of air were shown, contaminated with various amounts of carbonic acid. A syringe may be used instead of a phial of water to cause the movement of air, or a few drops of lime water may be poured into a phial containing air to be examined, making comparatime experiments with fresh air.

THIRD LECTURE.

This lecture was devoted to the warming, cooling, moistening, and drying of air, and the exclusion and correction of external vitiated air.

Great progress had been made in recent years in elucidating many of the properties of heat, in tracing its operation on different kinds of matter, and in perfecting and economizing the apparatus by which it could be rendered available for the practical purposes of daily life. The intimate connexion that had been proved to exist between heat, light, electricity, magnetism, and chemical action, had opened up new sources of investigation; but much remained to be done; for we were as yet scarcely beyond the mere threshold of discovery. In one and the same experiment an acid might be employed in conjunction with water to disintegrate and separate one by one the primitive molecules of a mass of metal, developing heat by the chemical changes thus induced, discharging electricity, which could be conveyed through a proper conductor, producing light on making or breaking contact with the wires employed to manifest the electrical action, and imparting magnetic power to iron and other materials.

We were no longer restricted to the ordinary fire-place, and though nothing could rival its agreeable cheerfulness and general utility, steam and hot water apparatus had given facilities that were unknown in former days.

The common fire radiated in the room in which it was placed in the same manner as the sun shone upon the earth, and would probably always continue the favorite in ordinary apartments. It had a peculiar charm in the ever-varying features of its luminousness that no other invention had equalled. The grand desiderata in respect to it were the right adjustment of its position in respect to altitude above the floor, which should not exceed from six to ten inches; the introduction of no more iron than was absolutely necessary for supporting the fuel below and in front; the size of the chimney, which was generally, till lately, four or more times larger than was requisite or desirable, wasting a great amount of air, and ventilating at a wrong level, unless special provision was made to counteract this defect. Many experiments were then described that had been made in reference to fire-places and flues, and one illustration minutely explained, where a flue nine inches square, and about twenty feet high, had worked four ordinary fire-places. These were afterwards closed above and in front, so as to be converted into furnaces, and, when in full operation with the same flue, each was found capable of melting iron with facility and rapidity. A register or valve was preferred near the top of the smoke flue, or, at least, at a considerable elevation above the fire. A special experimental illustration was then given of a circular fire-place, three feet in diameter, the red-hot fuel being visible and accessible all around it, and the products of combustion, accompanied by a blue flame, descending in the form of a circular wreath in the centre of the fire, and traversing the floor below, which was well warmed before they escaped into the chimney.

In England, though the open fire was usually accompanied by the production of smoke from the bituminous coal in common use, considerable progress had been made in the introduction of smokeless fuel during the last twenty years. In many buildings, soft coke or anthracite was employed, and Dr. Arnott had recommended a fire-place in which the fuel was kindled at the top in the same manner as a candle, all the smoke being consumed when the proper coal was employed, and sufficient attention paid to the construction and management of the grate.

In explaining the peculiarities of stoves, Dr. Reid insisted strongly on the excellence of those long used in the north of Europe, that were of considerable size, and had a pure porcellaneous surface. They were much larger than the iron stoves usually employed in this country and in England, extent of surface compensating for the want of intensity of heat, and the atmosphere they afforded being more grateful to the lungs and nostrils. Much ingenuity and skill were undoubtedly displayed in many of the stoves made in this country and the accompanying drums, but, as a general rule, the great majority he had seen were, when placed in the lower part of any building for general purposes, usually provided with pipes or channels for the ingress and egress of air that were far too small. They gave accordingly a sharp current at a high temperature rather than a large volume of a mild atmosphere. They were also generally without the means of supplying themselves with air from the house itself, instead of from the external atmosphere, an object of great practical importance in heating halls, passages, and public buildings previous to any occupation, or where a small amount of ventilation was sufficient.

Steam apparatus was then adverted to, the use of which Dr. Reid considered could be largely extended with advantages to individual habitations, even where the power of using a common fire was secured in the usual manner. It could be made to assume any desirable form. The principal difficulty in ordinary habitations was the boiler within doors. Great improvements had been made in modern boilers, so as to reduce largely any risk of accident, but the improvement considered most desirable was, that in which one boiler should be provided for a number of houses, and built in connexion with facilities for water baths, washing, &c., and from which steam for heating or culinary purposes could be supplied to each individual habitation in the same manner as gas, by special pipes. Steam, or steam power, could be rented in many places for manufacturing purposes, and there was no reason why similar facilities should not be extended to ordinary habitations in cities and villages.

Steam could be made to afford any required temperature, according to the form of apparatus used. With extended metallic rings, plates, or projections from the surface of a steam pipe maintained at 212°, a much lower temperature could be secured, corresponding with the amount of material in connexion with the pipe, and this form of apparatus, or hollow metallic cases with a limited supply of steam, necessarily gave a milder temperature. He did not consider a temperature of 212° objectionable when the air was pure, though he preferred a milder warmth; but higher temperatures, arising from the use of high-pressure steam, he had often seen attended with disadvantageous results, increasing with the elevation of the temperature sustained.

The action of the hot-water apparatus was then explained and illustrated by a glass model, in which colored water was thrown into currents by the action of heat, the warm water giving off caloric wherever it was desired, and then returning to the source of heat for a fresh supply. This heating apparatus was preferred to the high temperature stove and the steam pipe wherever a mild and continuous heat was desirable, and where it was not required to carry the pipes or apparatus containing the water to a very high level, the strain upon the joints of the apparatus being in proportion to the altitude of the column of water they contained. The water could be maintained continuously at any required temperature under 212°. Gas stoves had been introduced in many places with advantage where a small chamber was to be heated, and where there was no convenience for any other arrangement. A most pernicious practice was, however, prevalent where they were used, the products of combustion being permitted to mingle with the air of respiration in apartments not provided with ventilation. Thousands upon thousands suffered annually where gas lights or stoves not ventilated formed the only source of warmth.

Dr. Reid then pointed out the comparatively ineffective results that arose from the action of heating apparatus that conveyed warm air too quickly to the ceiling of the rooms instead of distributing its power on or near the floor. Railroad cars frequently presented a temperature above 212° at the ceiling, while on the floor the thermometer might be down to the freezing point. They gave an extreme illustration of numerous buildings where the introduction of arrangements for securing the full action of warm air at a lower level would add equally to comfort and to economy. The peculiarities of external warmth arising from the rays of the sun were then contrasted with that developed by artificial means. Saussure made an experiment in which air had been raised to a temperature of 210° by merely exposing a cork case with glass cover to the direct rays of the sun, and preventing the cooling influence of the circumambient air. The rays of the sun did not directly warm the air, but the ground, from which heat was transmitted to the air resting upon it. In the torrid zone it would probably be practicable, even without the use of lenses or reflectors, to develop heat sufficient to produce a limited amount of steam. A patent had lately been taken out for concentrating the rays of the sun upon boilers in such climates. The great practical lesson which all these points taught was that we should endeavor to warm the lower stratum of air effectually in individual buildings. If this primary point be secured, the upper portion will soon acquire the necessary temperature from the natural ascent of warm air.

The cooling of air was in some countries, and at particular seasons, as important a question as the warming of air in temperate and cold climates. In India habitations were sometimes built under ground, the family occupying a lower and lower flat or series of apartments as the external heat increased. The construction of buildings so as to take full advantage of the shade, and of the basement in making channels of supply, was seldom made a sufficient object of attention. The production of cold by the evaporation of water was largely introduced in many places with advantage; but where the air was highly charged with moisture this method was disadvantageous, tending to saturate it to an extent that interfered with the natural exhalation and evaporation from the surface of the lungs and of the body. By taking in air through apertures in turrets, or even by apertures elevated as much as was found practicable in different buildings above the level of the ground, great relief was often given. The warmest atmosphere in sunshine was generally at the surface of the ground, where no peculiar current or other special cause gave it a different position. In all cases where a ventilating power was available, the simplest method of producing a cooling effect upon the body consisted in inducing a current. A draught or current was agreeable or disagreeable, dangerous or salutary, in proportion as it was adapted to existing circumstances. The fan in a lady's hand and the punkah, or large fan used in India, were very different from the ventilating shaft or other instrument used to act on hundreds or thousands at the same time; they differed essentially in this, that while the former merely agitated the same air again and again, changing that portion in direct contact with the face or the whole of the body, the latter, in producing a similar effect, entirely changed the atmosphere charged with products of respiration or exhalation.

The use of ice, however effectual in cooling air, was generally too expensive. Underground channels cooled by a stream of water, removed or stopped when too much moisture was communicated to the air, were the most valuable and available means of reducing temperature; and where hot-water apparatus was provided for winter use, it might often be used as a cooling apparatus in summer by running a stream of cold water through it. The artificial evaporation of ether and water in rams could be also rendered useful in the production of cold, but no such apparatus had as yet come into general use, though perfectly successful in special experiments.

Moistening air was a comparatively simple matter, though often neglected. Very pure water should be selected for this purpose, and the evaporation should not be permitted under any circumstances where the water was apt to be decomposed. A porcelaneous or marble surface was preferred for evaporation. Iron was to be avoided, and steam from ordinary boilers, contaminated by oil or gases from corroded metals, was not to be used. Special copper boilers, set apart exclusively for this purpose, and block tin tubes, for the conveyance of the steam, were preferred in large buildings, where an atmosphere had to be provided for thousands at the same period. The steam prepared in this manner was also used to assist the heating apparatus. Whenever a thermometer with a bulb moistened with water indicated a difference of not more than five degrees lower than the ordinary thermometer, the addition of any further increase of moisture should be arrested.

Drying air is an operation for which no satisfactory process has yet been pointed out sufficiently economical to admit of its general practical application when air is warm and largely charged or saturated with moisture. When the temperature is lower, and the application of a slight elevation of temperature is not objectionable, the increased solvent power which the air thus acquires gives it practically a drying effect. In the sick chamber, in new buildings where the plaster was not dry, and in all limited or confined atmospheres where it was important to remove moisture, nothing was more effectual than newly prepared lime. Dr. Reid had used this largely in many buildings occupied soon after completion, distributing, in one case, cart loads of quicklime in the air channels and in the different apartments where the pressure of public business induced the authorities to occupy courts of law the day after very extensive alterations had been completed, without waiting either for the drying of the plaster in the usual manner, or for painting and decorations. When a building was surrounded with an external malarious atmosphere, by a right system of drainage this could in general be removed, at least from the immediate vicinity. Where the drainage was not sufficient, an active system of vegetation became the next resource. If temporary or other causes prevented this being carried to a proper extent, the antiseptic power of caustic lime could be applied with great success. He was prepared to point out many opportunities where this agent ought to be used in all cities he had hitherto examined. Numerous other chemicals could be rendered available, particularly choride of lime, muriate of zinc, and other substances. Their effects were seldom, however, obtained to the extent they were capable of producing, from a want of knowledge on the part of those who applied them of the chemical details essential to their full operation. Where vitiated emanations were traced within a building to any special drain, close chamber, room, or other space, either in the basement or elsewhere, a special ventilating power should be brought to bear on them in the same manner as the ventilating shaft exhibited had been brought to act upon all the materials used in the illustrations given at the experimental table, unless the cause was altogether temporary and easily removed.

FOURTH LECTURE.

The ventilation of individual rooms and habitations formed the most important question connected with sanitary improvements. These were the places where the great mass of mankind spent the larger portion of their time; where they were born and where they died; there they generally spent the period of their infancy and childhood, wheir days of suffering and sickness, and recruited their daily strength with food and by reposing from their labors. A vitiated atmosphere at home corrupted the condition of the blood more than any other cause, inasmuch as it had a more continuous power of operation. The effect of each individual inspiration might indeed be trifling, but when repeated twelve hundred times an hour for days, and months, and years, and brought in direct action upon the blood itself in the lungs, it was to be expected that it should soon affect every fibre of the living frame.

In studying the ventilation of individual rooms and habitations, it was recommended that the rotatory movements of air in a confined atmosphere should be examined when an inequality of temperature was induced, and that these movements should be rendered palpable by chemicals producing heat and smoke. Franklin had made use of this expedient, and had it been more generally attended to, ventilation would have made much more progress than it had done. Experimental illustrations were then given of these rotatory movements. In the external atmosphere the general ventilation of the globe depended on such movement. In the smallest space that man could examine they could likewise be traced. A peculiar argand lamp was then shown, in which hundreds of circular rings appeared when the air and gas were permitted to enter in special proportions. They afforded an example of minute rotatory currents indicated by the movement infinitesimally small particles of incandescent carbon. The audience were invited to examine these individually at the end of the lecture, as they could not be seen at a distance. Bearing in mind the fact that the living body, unconsciously to the individual, ventilates itself when this operation is not opposed by an air-tight or ill constructed apartment, an aperture for the ingress and egress of air in a proper position, and of the right dimensions, is the great desideratum. While a window serves this purpose, and a porous curtain diffuses the entering and out going air, it has taken a long time to carry conviction of the importance of additional resources in the comparatively air-tight structures of modern times, charged with products of combustion from gas and respiration, as well as other varying impurities. But when it is recollected that a thousand different circumstances arising from the peculiar position, form, structure, arrangement, furniture, and occupation of rooms, as well as their aspect in relation to the sun, prevailing winds, local influences acting on the air, the position of doors and windows, constitutional peculiarities, and many other details that might be enumerated, in addition to the changes of the season, the time of day or night, and the number of persons present, all contribute to modify the effect required, it will be obvious that the window alone is not sufficient for every ordinary apartment.

The great desiderata, in addition to the window, at least in rooms subject to a great variety of occupation, are the following:

1. A special flue, from the highest portion of the room, for the discharge of vitiated air.

2. A special aperture for the ingress of a warmer or colder atmosphere, when the external temperature, dust, noise, or any other cause, renders a supply by the windows objectionable.

3. The means of extending the diffusion of the entering air so that it shall not impinge offensively on any individual.

4. The means of applying a force or power to the ventilating flue, (heat is the most available for all ordinary purposes,) which shall increase the discharge to any required extent, and cause fresh air to enter by any channel provided for this purpose.

5. The exclusion of all vitiated air from the basement of the building, or any other source, either by the action of a ventilating flue or other equivalent measures.

These objects can, in general, be attained with facility and economy in building a new structure, without interfering with the usual details of construction to any objectionable extent. It forms a most important addition when the passages and staircases can be converted into means for the general supply and discharge of vitiated air, warming the air by an apparatus placed there at the lowest available level, and introducing a large internal window above every door communicating between the passage or staircase and individual rooms. These, when open or shut to the required degree, allow the air in the passages and staircase to be used as a milder climate, whether in the heat of summer or the severity of winter—a perpetual ingress of fresh air and discharge of vitiated air being constantly maintained in the hall, passages, or staircase.

Dr. Reid then adverted to some models and to a series of diagrams, with which he illustrated, practically, the various methods adopted in experimenting on the subject, and in the construction of apartments where ventilation was introduced under very different circumstances, from which we select the following examples:

1. In this case, the ventilating aperture was immediately below the ceiling and above the window. A valve regulated the amount of opening. The air entering or escaping by this aperture must pass through a plate of perforated zinc about one foot deep, and extending the whole breadth of the window. Area of aperture through the wall nine inches square.

2. A room having a ceiling universally porous, the air entering between it and an air-tight roof, and two apertures communicating with this cavity and the external air which descends from one part of the ceiling and escapes at another.

3. A room where the fresh air is supplied from the whole surface of the wall in which the chimney is placed, excluding those portions below the level of the fire-place; vitiated air escapes by a special flue contiguous to the chimney.

4. A room in which, when crowded, fresh air can be admitted freely through a porous door from a prepared atmosphere in the passage, vitiated air being permitted to escape by a large panel or window above the same door.

5. A house having a special ventilating shaft capable of acting on all or any of the individual rooms, and of having its power increased, when necessary, by the action of heat.

6. A house in which all the vitiated air-flues are led into one large flue descending to the basement, passing then laterally into an adjoining shaft, whose altitude (from the basement to the roof) gives it great additional power when the fire is kindled at the lower extremity.

7. A house in which fresh air is supplied to the passage, stairs, and principal apartments, from a special turret on the shaded side of the house, while a discharging shaft, as in No. 6, commands the escape of vitiated air.

8. A house in which the heating apparatus (hot water) is so arranged as to present a warm surface on the floor of the staircase and principal apartments. Similar arrangements can be made with steam apparatus.

9. A series of habitations supplied from a general source with a ventilating power, and a steam tube in every house, and in every room of each house, where it is desired, in the same manner as houses are supplied at present with water and gas from one common source.

10. A series of diagrams, showing the imperfections of ventilated

apartments, under different circumstances, when not constructed with the resources explained.

In all these examples, whether apertures alone were made in humble apartments, or an extensive series of arrangements in first-class habitations, nothing was done incompatible with the free use of an ordinary window, or the action of a stove or open fire-place. The only peculiarity that required attention was, that there should be an ample supply of air in proportion to the demands made upon it. There was then no conflicting action between fire flues and the ventilating flues.

It was strongly recommended that the shaft or flue for the escape of vitiated air should always be constructed so that external wind should have no effect in producing a back current. No external top is better for this purpose than that recommended by a committee of the American Academy of Sciences at Boston. It differed from the cone in common use in this country, in having an addition above the top of this cone which expanded the aperture slightly above the line of the ordinary discharge. The ordinary form of cone of Mr. Emerson had the advantage of being more simple, though not so powerful in producing a draught. It ought to be recollected, however, that such terminations to ventilating shafts or flues were principally important in counteracting the influence of wind. They had no power in a calm. If heated by the sun, they would promote ventilation; if cooled by the state of the atmosphere below the temperature within doors, they would retard ventilation.

Dr. Reid concluded this lecture by a brief exposition of the condition of the habitations of the people in different cities in Europe, and illustrated by a drawing the numbers often crowded on a given space in many of the humbler dwellings, and houses of refuge for the destitute.

Bad ventilation was by no means confined to the abodes of the poor. None suffered more at times from this cause than the opulent in palatial edifices where extreme illumination and air-tight construction prevailed, though their wealth gave them great advantage in other respects. But great improvements had been made in all classes of habitations within the last twenty years, however defective individual examples might be. It was in vain, however, to insist on ventilation where there was a deficient supply of warmth and food. The general condition and health of the people was greatly influenced by the air they breathed, and this, in the course of time, affected the appetite; then the health gave way rapidly from the combined influence of bad air and want of nourishment. The low tone of the constitution induced a craving for unwholesome stimuli which affected the system still more powerfully. In one house inspected, near St. Paul's cathedral, in London, one hundred and twenty-three persons were found crowded in a few rooms; and in another, thirty or forty people were occasionally found in a single room. So great was the crowding of the poor in many of the most populous cities, that the question had been publicly taken up, and model lodging houses introduced, which, with the supervision of licensed lodgings, promised to be of inestimable value in improving the condition of the humblest portion of the population. He found that model houses had also been constructed in different cities in this country, some of which he had inspected with much interest. He did not know many questions connected with the material well-being of man more important than that of improving the condition of the dwellings of the people. It was every day becoming more and more a moral, a religious, and a political, as well as a physical question. Many were driven to the very extremes of socialism in its most repugnant forms as often from the want of proper habitations as from any other cause. If the family system and the home circle were essential to the foundation of a nation's prosperity and happiness, then too much importance could not be attached to the improvement of the habitations of the people. Wherever the laws, the institutions, the state of morals and religion, and the resources of a country led to their being carefully made, the effects were manifest in the external aspect of the people, to say nothing of the many other blessings that flowed from this source. But let them look to the other picture, and there it would be seen that if this object were neglected, whether from defective legislation, imperfect adaptation, or careless and indifferent landlords and proprietors, vice and intemperance were certain to mark the results. It was by no means desired to attach an exclusive importance to this question of the habitations of the people. It was only one of many causes that contributed to their elevation and comfort, or to their misery and degradation. But viewing this matter in a practical manner, it was obvious that the greater the degree to which science perfected and economized the means of combination and improvement, sustaining at the same time all the peculiarities and associations of individual families, the greater would be its success in promoting the best interests of the people.

Dr. Reid then adverted to the general appearance of the population in different European countries, and remarked that he had nowhere seen such marked specimens of sturdy and robust health and comfort as the Swedish guard, at Stockholm, presented when he visited that city. The soldiers were not tall, but they had a firmness, density, and compactness of limb and muscle which he had never before witnessed in any body of troops; while their countenances evinced a composure, along with an entire absence from care, dissipation, or fatigue, that manifested at a glance the high condition of their health. It would be important if in every city there was at least one trained band of men who could be seen from time to time, and give an example of the appearance that human nature ought to present amidst the mass of inferior constitutions that appear in cities, whether arising from bad air or any other cause.

FIFTH LECTURE.

On this occasion, Dr. Reid commenced with a reference to his preceding lecture on individual rooms and habitations, and called the attention of the audience to numerous cases that had come under his notice, both in this country and in Europe, where a great amount of vitiated air prevailed in the upper portion of different buildings. There vitiated air was prone to ascend by passages and staircases from other apartments, and if the roof or ceiling of the attics had no adequate discharge, the moisture of respiration was condensed during the cool of the night, though the warmth of the sun gave an elevated temperature to this space during the day. He had seen numerous houses where dry rot from vitiated air had entirely destroyed floors in the attics, while the lower floors were comparatively sound. In public buildings the same tendency was equally manifested under parellel circumstances. An example was cited of a church in Scotland, near Edinburgh, where the upper part of a long ladder was found so completely decayed that it was broken with facility by the hand, while the wood of the lower portion was perfectly sound. This church had been ventilated apparently by apertures in the ceiling, but there was no discharge above in the roof, so that they were totally useless, except in so far as they permitted the air in the roof to add its volume to that below; but at night the moisture of respiration condensing on the timbers of the roof, which were finally entirely destroyed by the dry rot. In London a very marked case occurred in the new post office, where, a few years after it had been occupied, large quantities of a brown fungus were found in the roof extending in branches sometimes ten, twelve, or sixteen inches long, and as thick as a man's finger. The products of respiration and of the gas lamps below had formed the food that supported the growth of the fungus.

The ventilation of public buildings was the next subject of consideration. The same principles were applicable there as in the ventilation of individual habitations; but the numbers crowded in a given space, the fixed position and comparative restraint that necessarily accompanied many of the duties of official life, the long sittings of a judge in court, of a member of the legislature, according to the public business transacted, the ever-varying numbers present, and the changes of the external atmosphere during long protracted investigations and debates—all conspired to render a degree of control and power of ventilation requisite that was not needed in ordinary apartments. Further, in public buildings, large halls, corridors, and passages were often necessary, besides numerous individual apartments applied to very various purposes, and subsidiary to the principal assembly rooms for the transaction of public business. These varying in number from one or two to hundreds, and sometimes covering several acres of ground, in many cases required to be ventilated in unison with the principal assembly rooms; and without the adoption of some general system for the whole, the warming and ventilating would be equally defective and incongruous with the architectural character of the building were the different portions of it erected without reference to any general plan.

The first point to determine, in the construction of a large building, in reference to warming and ventilating, was the number of apartments, halls, and passages that were to be used in such a manner, or so arranged that they must be subject to one system of ventilation to maintain uniformity of action. Then came the determination of the question, how far it was necessary or desirable to unite the varied groups of apartments and of individual rooms that required the power of independent action in a more comprehensive scheme, that would economize and facilitate the whole operation, without sacrificing the special requirements of each separate control?

These preliminaries being settled, the next step was to determine whether a ventilating shaft, put in action by heat, should be resorted to for the necessary power, or a mechanical instrument sustained by a steam engine or any equivalent force.

Where offices occupied by a few individuals only were to be ventilated, and where they were only required for very brief periods, neither large shafts nor machinery might be requisite, if proper apertures for the ingress and egress of air were arranged, as in well-ventilated individual habitations, with small ventilating shafts or flues.

A shaft being made to operate on the vitiated air to be discharged, tended, more or less, to produce a comparative vacuum in the apartment to be ventilated, and hence the origin of the term *Vacuum ventilation.*

An instrument moved by mechanical power, and acting directly in expelling vitiated air, produced a similar effect. But when it was made to ventilate by blowing in fresh air, it tended to create an excess of pressure within the apartment it ventilated; air then escaped outwardly by open doors and windows, as well as by any appointed channels, if they were not extremely large. This was termed *Plenum ventilation.*

In the most perfect form of ventilation, the ingress and egress of air were so nearly balanced that there was little or no tendency to the air being drawn inwards or pressed outwards at doors or other apertures not provided for its regular ingress or egress. The less the tendency to either plenum or vacuum ventilation the better. And even where shafts alone, or instruments alone, were used, it was always desirable to reduce the tendency to a plenum or vacuum as much as possible by the right adjustment of supply and discharge. In law courts, theatres, or assembly rooms of great complexity, and having numerous entrances to galleries, to seats on the floor, and to special places allotted for particular purposes, and still more if they were subject to great fluctuations of attendance, a plenum and vacuum power was combined where the greatest perfection of effect was desired.

Having determined on the leading arrangements for the supply and discharge of air, the amount to be given per minute, the apparatus required for heating, cooling and moistening, and any of those endless varieties of contingencies which each individual building might require, whether from the purposes to which it was to be applied, the locality in which it was to be placed, or the climate to which it was subject,—the details of the supply and discharge, the position of valves, and the precise arrangements required for the ingress and egress of air, should then be planned. This, in general, will be found to require much more attention than was formerly given to such questions. It is the rock of difficulties in all disputes where separate authorities are responsible for decoration and structure, and for the comfortable and effective result of ventilation. If the architect do not profess ventilation, or the authorities do not confide that department to him, it will be obvious that if no right mutual understanding be amicably and accurately carried out, then an *imperium in imperio* will interfere at every step. If the architect have supreme power, then he must necessarily become responsible for the ventilation, particularly if he controls and determines the apertures for ingress and egress, and the amount of diffusion given to the entering air. The ventilator cannot be responsible for his plans if he disapproves of alterations which the architect may carry into effect. Again, if the ventilator shall have the directing authority, the architect may say that he will not be responsible for the appearance of decorations and their general effect if they are adapted for ventilation in a manner of which he does not approve. It will be obvious, then, that until schools or colleges of architecture shall give the future student the opportunity of applying himself to this subject as much as its importance demands, we must consider this branch in a state of transition. When the architect does not profess to attend to ventilation, it cannot receive from him that full assistance and development which could otherwise be given in the original design, and in harmonizing all the conflicting claims of the different departments of the profession.

Dr. Reid then gave experimental illustrations of the action of ventilating shafts worked by heat, of steam ejected from a small glass boiler, and of different classes of instruments for the movement of air, pointing out more particularly the difference between the air-pump, the screw, and the fanner. In speaking of instruments alone, he gave a decided preference to the two latter, from the simplicity, continuity, and equality of their action; though, in particular cases, where air at a higher pressure than usual was necessary, he preferred the air-pump.

At the same time, wherever a ventilating power was essential, and the difficulties to contend with were not great, he recommended the shaft as abundantly sufficient for all ordinary purposes; stating that any common laborer could be taught to attend to it, and that it merely required to have a proper supply of fuel from time to time; whereas, with an instrument worked with an engine the constant attendance of an engineer was essential. That was the result of his experience. He had been the first, so far as he was aware, to introduce large fanners, worked by steam engines, fitted up expressly for ventilating buildings, and still recommended their use as much as before, under similar circumstances; but he could point out places where they were not necessary, and where the substitution of a shaft would effect a considerable annual saving.

In respect to the course which the air should take in passing through any apartment to be ventilated, much should depend on the special difficulties to be overcome in each individual case. The ascending movement was preferred for all ordinary purposes. He had used that movement more extensively in public buildings than any other, though in old buildings, where it had to be applied under great limitations, there were often many difficulties to be met. Among these the most formidable in general was the want of sufficient diffusion for the entering air. In the late House of Commons, which was made the basis of experiment for determining the accuracy of his views and the test of their application to the new houses of Parliament, he had been led to the conclusion that the restrictions which the state of the walls and the time for applying his plans in this building necessarily imposed on him, universal diffusion through a porous floor was the only scheme of supply that met the realities of the case. This arrangement for the supply he introduced accordingly; and, for fifteen successive years, after which the building was pulled down in consequence of the progres of the new works, the government and the House uniformly supported it, notwithstanding some obvious disadvantages that were met by peculiarities of details. The House of Peers, also, after it had been sustained for three successive years, requested that similar arrangements should be introduced into their chamber; but the means allowed for this purpose did not permit the views to be applied as completely as in the House of Commons—the progress of the new works leading the authorities to expect that they would soon be enabled to occupy the new House of Peers.

Tables were then presented, showing the observations that had been made every hour during the sittings of the House of Commons for fifteen successive years. Large diagrams were also shown explanatory of all the peculiarities of the arrangements adopted in the late House of Commons, and of the experimental buildings previously constructed by the Lecturer at Idinburgh in reference to the ventilation. In the temporary House of Peers arrangements were made that enabled a large movement to be tested whenever the weather gave a suitable temperature, according to which fresh air was permitted to descend from one part of the ceiling and ascend to another. This was independent of the usual arrangements adopted there. A similar movement had also been in use in his lecture-room at Edinburgh from the time it was constructed in 1833; but there he did as he pleased, and gave a supply and discharge by a large aperture having an area of several hundred superficial feet. The wall of one side was left out in reality, so that air descending from the contiguous apartment moved in one broad current to the class-room. A movement of supply and discharge by the ceiling requires a very large amount of apertures, otherwise much of the air passes from the aperture of supply to the aperture of discharge without doing any good to the ventilation of the lower part of the room, where alone it is essential to have fresh air. Again, there are cases where a direct descent is preferable to all other movements. These occur principally where there are peculiar difficulties connected with the supply and the condition of the floor. At one period he (Dr. Reid) was under the impression that such a movement might have been the best for the old House of Commons; but, on investigating the circumstances that led to this view, it was found that the whole arrangements for the ventilation had been improperly changed and neglected during his absence, and, with the sanction of the government and the members of the House of Commons who attended the investigation, everything was restored to its former position.

Descending ventilation could be rendered perfectly successful even in a crowded assembly, but never without a much larger supply than was requisite with an ascending movement. He had made the experiment repeatedly with individuals, and in a room specially constructed for testing this and other questions connected with architecture, and the result was invariably the same. Descending ventilation was also inapplicable where lights were introduced that were not specially ventilated. Where the products of gas and oil lamps were added to the products of respiration the amount of ventilation requisite was so large as to preclude a proper supply without a movement of air so great as to be objectionable on this ground alone, and, at the same time, very expensive.

In some experiments, in which a number of the members of the Royal Society of Edinburgh took a part, one of the clubs formed of members of the society dined in one of the experimental rooms he had constructed. Fifty attended on this occasion, including the president, Sir Thomas Brisbane, the late Lord Cockburn, and other gentlemen connected with literature and science. The hotel-keeper at whose establishment the club were in the habit of dining was well acquainted with the habits of those who were present, and stated next day, when he presented the bill, how much he was surprised at the amount of wine taken on this occasion. This, at least, was the point that principally attracted his attention. After providing rather more than a good average supply, he had to send a carriage for more, and again, as the evening advanced, he had to send a second time for further supplies. The dining room at his hotel was not then, at least, ventilated, and gas and vitiated air from respiration soon satisfied the appetite. But in a room supplied with a large and flowing stream of air, the natural powers of the constitution were not subdued, and, what is curious, none of those present were at all aware that they had taken anything unusual till they were informed of it next day. Many is the unrefreshing meal and subdued appetite that destroys the strength of the constitution in apartments loaded with the vapor of respiration and exhalation. Travellers, and, indeed, all persons, should be charged only half fare when they partake of refreshments in an ill-ventilated apartment.

If one wishes to see and study the practical importance of this question, let him go to ill-ventilated boarding-houses, schools, milineries, manufactories, and refreshment rooms, particularly in the crowded localities of large cities, and he will there trace one of the causes of impaired health which affects great numbers of the population. So thoroughly is this now understood in many places, that cases have been cited where workmen have struck for more wages in newly ventilated manufactories; the proprietors not perceiving that they could, in general, obtain an equivalent value from the exertions of those who were in better health and strength than the ventilation previously permitted.

Diagrams were then pointed out illustrative of the general mode of dealing with the ventilation of large buildings, special reference being made to the houses of Parliament, in London, and to St. George's Hall, at Liverpool.

SIXTH LECTURE.

In this lecture details were given as to the arrangements made at the late House of Commons, and contrasted with the provisions founded on them that had been executed for the application of his plans in the new houses. It was only right, however, that he should tell the audience that they were not completed under his directions; and that his plans there met with so many obstacles from alterations, to which he objected, that, in the year 1845, he considered it his duty to call the attention of the government to them, and to the necessity of an investigation. It being evident that he could no longer be responsible for the result, or for the cost, unless sustained in the arrangements authorized by the government and Parliament at the time his plans were adopted. He continued that it would be altogether out of place in so brief a course, to detain the audience with any minute statement of his own, or of others, on such a subject; but it would be equally obvious that he could not pass over this subject without some notice of the principal incidents that had occurred in so great a work, and he would, therefore, only give a very general outline of the case, and place in the hands of the secretary of this institution a copy of the evidence he was finally called upon to give openly and publicly at the bar of the House of Commons in respect to it, after demanding this or some equivalent opportunity in vain during the six preceding years.

The investigation he asked for was instituted in 1845, and in the following year a committee of the House of Commons took up the question. The committee included members of all political parties; the late Sir Robert Inglis was chairman, and Lord Palmerston and Lord John Russell were both members. After due investigation the committee passed resolutions that were in every respect satisfactory to him, and they also renewed, as a committee, their expressions of opinion as to the satisfaction given by the plans in the house they then occupied. But in the meantime new proceedings were instituted in the House of Peers, and after this renewed investigation by new referees, and by a committee of which the Marquis of Clanricarde was chairman, in a manner that did not permit, as Dr. Reid had then stated publicly in official documents, a proper investigation; a resolution was carried in the one house of Parliament, the House of Peers, that virtually negatived the resolution unanimously adopted previously by the committee of the House of Commons, and gave an authority to the architect over the ventilation to which he, Dr. Reid, could not assent. From the day this was officially communicated to him by the government he never once acted at the new houses, except under protest, though he gave such advice as the government still required from him, till he succeeded in being called to the bar of the House of Commons. But in the meantime the mayor and corporation at Liverpool had adopted, in the year 1841, the same year in which his plans had been adopted for the new houses, parallel plans for their great building, St. George's Hall, and the new assize courts. In 1846 the Liverpool committee inquired into the disputes at Parliament, and coinciding with the views of the House of Commons, and not with those of the House of Peers, continued the support they had all along accorded, and, in 1855, when the whole works were completed, declared their satisfaction with the result. A committee of the House of Commons also had previously reported their success. Further, in an arbitration, in 1853, when a new investigation took place that lasted for thirty days, the arbiters sustained him in every legal privilege and award connected with his case, of which, at the new houses of Parliament, an attempt had been made to deprive him, founded on the evidence of the architect, with whom he differed.

If any one should think that even with this brief statement he had dwelt too much on this subject, he requested them to remember that he could not say less without appearing to evade a case that had led more to the study and progress of ventilation than any other with which he was acquainted; which had materially assisted in supporting the views he had previously expressed, and explained in his Illustrations of Ventilation, published by Messrs. Longman, of London, as to the right method of proceeding with the study of architecture and ventilation for the future, as well as to the mode of meeting the difficulties attending a state of transition in making preparation for systematic ventilation.

The late houses of Parliament, the new houses, St. George's Hall, and the new assize courts at Liverpool, a building in which there were upwards of a hundred public and private compartments, and the experimental rooms and lecture room he had previously constructed at Edinburgh, presented in their combined history the most extended illustration of the applications of his views. The obstacles opposed to them at one place, and their execution in another, under such a variety of circumstances, exclusive of law pleas, arbitrations, parliamentary, professional and other inquiries, called forth facts which elucidated the progress of all the leading questions affecting warming, lighting, ventilating, drainage, and acoustics, in connexion with the progress of modern architecture, and the difficulties they had to encounter.

A diagram was then explained, illustrating the numerous rooms subjected to the action of a single shaft at the late houses of Parliament, and the manner in which it was applied in acting, at the same time, on the chimney flues, on the drains in the vicinity, and on vitiated air when accumulated in the contiguous court-yards. Plans and sections were also shown, illustrative of the works executed under his direction at the new houses, which were incorporated with the principal portions, till he refused to be responsible, and ceased to act, except under protest. The sections explained the portions of the Victoria and the clock towers set apart for the supply of fresh air from a great altitude, the central air chamber under the central hall, the leading channels from it to the House of Peers, to the House of Commons, and to other parts of the building, and the passage for vitiated air from several hundred different places, and from all the smoke flues to the central tower above the central hall, which had been introduced expressly at his suggestion, but subsequently so reduced and cut off from important channels that it formed one of the principal causes of dispute.

The plans showed the general disposition of the fresh air chambers in the vaults, and the great smoke and vitiated air flues in the roof.

Dr. Reid then concluded his remarks on the new houses of Parliament, stating that though alterations had been made in his plans every succeeding year had confirmed him in the opinion that they could not depart in any material point from the principles he had advocated or the practice he had introduced without injury to the ventilation. He added that he had reason to believe that this conclusion would be placed beyond all question whenever the evidence taken at arbitration should become better known; referring to the numerous works he had executed, and to the extent they had influenced others, he mentioned one architect, Mr. Thomas Brown, who had applied his plans in forty-eight public and private buildings.

A large plan was then brought forward showing the details of the principal works executed under his direction at George's Hall, Liverpool. The principal air channels were about 400 feet long, and of such magnitude that any one could walk in them without inconvenience. A central engine commanded the movement of air, and drove four instruments that directed currents north or south, east or west, as might be required. The great hall, the courts of law, the minor courts, the library, the concert room, had the combined advantages of a plenum and vacuum movement. Heat was given by coils of hot water apparatus, the principal coils being each forty feet in length, ten in breadth and six in depth, and auxiliary coils of steam pipe were placed locally, whose action was brought into play principally in very cold weather. Many portions of the structure showed special modifications in the design of the interior for ventilating purposes. All the smaller apartments had fire-places supplied with a soft coke that gave no smoke, and the flues were all carried into four large shafts in the angles of the great hall. No windows were ever opened in the great hall, law courts, or concert room, but in most of the minor rooms and offices windows were made in the usual manner.

When air is supplied to large buildings, or, indeed, to any habitations by a fixed and definite channel, it is very desirable, if it be not introduced from a great hight, to pass it through a gauze in winter, in such towns as London and Manchester, so as to exclude a large portion of the soot that usually accompanies it at such periods. By taking the additional precaution of making it traverse a heavy artificial shower of water, which is still more purifying, if charged previously with as much lime as it can dissolve, the air becomes much more refreshing.

Thus, then, in public buildings of the highest importance the great objects are, the supply of the purest accessible atmosphere; the purification of the air when requisite; the exclusion of all sources of local contamination; the power of warming by a mild heat; the power of cooling; valves and channels that admit of air being changed in temperature at a moment's notice, or, at least, sooner than numbers can pass out of or into the building ventilated; means for moistening air; the ventilation of lamps, or the adoption of a system of lighting that excludes the products of combustion; the introduction of a plenum or vacuum power, or of both, for regulating the supply of fresh air and discharge of vitiated air; and the adoption of the most extensive measures practicable for securing the supply of air with the gentlest movement, and through a very large diffusing surface, which is more and more agreeable in proportion as it approaches universal diffusion from every perpendicular surface. The diffusion may, in some cases, be given at the ceiling, under certain circumstances of breadth and height, excepting such area as may be reserved there for the discharge of vitiated air.

Leading facts were afterwards pointed out in reference to other classes of buildings, in which his plans had been introduced, from which the following selection is made:

The Chapel Royal, at St. James's Palace, is ventilated by a metallic shaft, worked by a series of gas lights, and the principal fire-places discharge vitiated air into the same flue, with which they communicate by copper tubes. There is an ascending movement of air in the body of the chapel, but in the Queen's gallery the fresh air descends from the ceiling and spreads horizontally over the seats.

At the Pavilion, in Brighton, ventilation was effected by the introduction of an iron shaft, heated by gas, and attached to one of the turrets in the vicinity of the Minarets.

At Buckingham Palace, in ventilating some of the state apartments, a central shaft, having an area of twenty-seven feet, was formed where only two feet of discharge had previously been provided, exclusive of doors and windows. A back staircase, eight feet in diameter, was appropriated for the discharge of vitiated air from the basement and contiguous offices, which had previously flooded the state apartments.

At the opera, in London, a discharge two feet in diameter was replaced by another of seventy-five superficial feet area, but nothing was done for the better supply of fresh air, except at the Queen's box. The proprietors would not agree to give a proper supply.

At the Old Bailey the whole of the arrangements were adapted to the action of a large fanner, eighteen feet in diameter, which was worked by a steam engine.

In churches, the spire or tower was brought into action as a ventilating power, whenever permission was given for this purpose; and when the church was surrounded by a grave-yard or other source of vitiated air it was recommended that the spire should be so divided within that one part might supply fresh air from a considerable altitude above the level of the ground, the other portions being used for the discharge of vitiated air at a higher level.

In prisons, Dr. Reid had used the ventilating shaft principally, and preferred an ascending movement in the individual cells, allowing the prisoner the control of the window to a limited extent.

In barracks for soldiers great suffering was often experienced from defective ventilation, and the men often became practically familiar with this question from the extent to which their arms and accoutrements rusted in some places compared with others, entailing on them a degree of labor, in preparing for parade, of which they made more complaints than of its influence on their health.

In schools, he preferred the action of a single ventilating shaft sufficient to control the ventilation of every apartment in the building, and urged also the general adoption of one regulating discharge from each room. Illustrations were taken from schools in Westminster and other places, and cases cited where excessive crowding had led to six times the number originally intended being accommodated in particular schools. In this country his own observation, as well as the concurring testimony of different reports he had seen, led him to the conviction that much was still to be done before the ventilation of schools could be considered on a proper footing. The supply was, in general, too small, the means of discharge not sufficiently powerful, and the ascent of the warm entering air so rapid, that much of it escaped by the ceiling without doing any good, unless made to descend to the floor by opening the discharge there, and closing the aperture above, when the products of respiration descended along with it. The diffusion of heat, also, was rarely general and equal, and hence it was often impossible to give sufficient fresh air without opening the windows at times when the state of the external atmosphere indicated that they ought, if possible, to be closed. In some more recent cases the diffusion of heat had been very much extended and improved, but not the ingress of air.

In hospitals much required to be done, more especially where contagious diseases were treated; he considered that great improvements might be made in such cases by causing all the expired air and exhalations to pass directly from each individual patient to a ventilating flue, where, by the action of heat, every noxious emanation could be entirely destroyed, so as equally to save life within doors and relieve apprehension without. In this country, at the New York Hospital, he had seen arrangements that were in advance of most of the plans usually adopted in Europe; but he had not hitherto observed any hospitals where the views he recommended for quarantine hospitals on shore and others for contagious diseases had been introduced.

In chemical lecture rooms, experimental class rooms, and in all manufacturing operations, where acrid, poisonous, or irritating gases and vapors were diffused, he recommended that provision should be made for the direct removal of every offensive product without permitting it to escape into the general atmosphere, illustrating this department of the subject by a large plan of the ventilating shafts and flues introduced at his former class-room in Edinburgh.

From these illustrations it would be seen that the course he recommended was a special adaptation in each individual class of building to the purpose for which it was erected, and in unison with the style of architecture adopted. Air could be made to move in any direction that might be required, and when in a proper condition as to temperature and moisture, and in sufficient quantity, many of the details were often matters of indifference. But the economy of each individual movement was a very different question, and extensive ventilating movements could only be most successfully and economically combined when incorporated with the original design before the building is commenced.

Dr. Reid then passed to the subject of lighting public buildings, and commenced his illustration by throwing a very powerful lime ball light on the flame of candles, lamps, gas-lights, burning alcohol, and paper. These, under the influence of the lime ball light, gave a shadow on the adjoining wall which did not terminate with the outline of the flame, but merged without any line of demarcation at the upper part of each flame in a continuous ascending undulatory shadow that reached to the ceiling of the lecture room. The apparent shadow arose from the refraction produced by the heated current of ascending vitiated air, and the necessity was then pointed out of all lamps used in public buildings being ventilated by special tubes, or of ventilating apertures being arranged for the discharge of vitiated air above them, so as to prevent the recoil and descent of vitiated air from the ceiling. In an assembly for the transaction of business, in a church, in a school, in courts of law, and in other similar collections, it was too often forgotten that the object to be attained by lighting was not so much to show a beautiful chandelier as to illuminate the countenances of those who took a prominent part in the proceedings.

A visible light close to any object, or in the direct line of sight between one person and another, interfered with distinct vision. In a light-house the light was the special object of attention, as in fireworks, and in various optical, electrical, and chemical experiments; but in public buildings, such as had been adverted to, the less the actual flame or luminous matter was seen the better, provided the proper objects were well illuminated. The more successfully the diffused light of day was imitated, and the light by night corresponded with the light required and given by day, the more satisfactory would the result be. But many were the buildings in which the light by day as well as that by night was very imperfectly adapted to the necessities of the case. In his experience, at least, he had often seen the back of the head illuminated more powerfully than the countenance, and a distraction of rays and beams of light utterly at variance with that harmony and unity of effect that was always manifested in an external landscape, when there was no disposition nor attempt to gaze upon the sun itself in its meridian splendor. The different steps in the progress of this question were then explained; the successive experiments made at Edinburgh, Liverpool, and London, and the final acknowledgment of the principle that the products of combustion from lamps, as well as the heat they produced, should be excluded or withdrawn as much as possible from ventilated buildings, where the heat was not rendered useful in unison with proper ventilation. That electrical lights, oxygenated lights, lime ball, and other lights of great intensity, were not so much required, at their present expensive cost, as a mild and diffused light illuminating the objects to be seen, and which should not glare in the eye of the observer. That the countenance should be illuminated by rays extending from an expanded surface, and rather from above downwards, than from below upwards, always securing, directly or indirectly, as much horizontal light as was required. That lights at a low level, as foot-lights, such as are common at theatres, give an unnatural expression to the countenance, and also interfere materially with distinctness of vision when hot currents of air are permitted to ascend from them, by the inequality of the refraction of light transmitted through such heated currents and the contiguous colder air. That the new resources placed at the disposal of architecture by the progress of practical science, and particularly by the facility which iron and glass afford in arrangements for lighting and ventilation, call for a revision of the practice of former days and for the more extended use of external illumination, or the introduction of ventilated lamps. That phosphorous was an element that might be advantageously introduced for the purpose of artificial illumination, the acid formed by its combustion being condensed by ammonia, and returned again by chemical processes in the form of phosphorous. There was no objection to bright lights if the rays from them were sufficiently diffused before they met the eye; but until economy was attained in their construction and management, a double expense was incurred, first in producing them and subsequently in moderating their intensity.

The physical effect of light upon the constitution was then adverted to, and illustrations given from a barrack in St. Petersburgh, where a very marked example was presented of this influence in the prevention of disease. If the rays of light were capable of producing those striking and delicate results that were portrayed by the daguerreotype and the photograph, it would be unreasonable to suppose that their action on the sentient fibres of an organized and living structure would not be still more marked. The influence of light was equally conspicuous on the animal and vegetable kingdom; and the tint given to rooms could be used in some cases of disease as a power in assisting to sooth and subdue an irritable temperament, or in raising, in some degree, the spirits of those that were depressed. He had had, on different occasions, the opportunity of noticing the effect produced in this manner. A room that was of a dead black, and another in which pink and white alternated, were at the extremes of the scale.

The electric light was the most intense and penetrating artificial light hitherto discovered; and next to it came the lime ball light. The electric light was accompanied with a perpetual vibration that had not hitherto been overcome; but the lime ball light could be sustained indefinitely and with great equality, by the use of appropriate apparatus. The late Sir John Leslie had estimated that the brightest lime ball light had only a one hundred and twenty-third part of the power of an equal amount of solar radiation.

This lecture was concluded with an account of some experiments he had directed for illuminating the hills at Edinburgh on the occasion of a public festival, when the scenery was made manifest by tons of blue light and other deflagrating mixtures, fired by signals on selected spots on different hills. Nearly a hundred persons were employed on this occasion, and the magnificence and beauty of the effect produced, where isolated landscapes started suddenly into view in the midst of the surrounding darkness, and where the illuminating lights were not seen, confirmed the views he had advocated in reference to the lighting of public buildings. He did not mean to say that naked lights should not be used, and that the light itself should not be visible in all kinds of public buildings. This was not requisite; nor was it so economical. Lights, also, were pleasing adjuncts in the ball room and on all festive occasions, where their sparkling brilliancy added to the gaiety of the scene. In this respect the pure white wax candle, with its brilliant flame, was unrivalled, except by the small gaslight burning with similar lustre. But he did maintain that the best style of lighting is that which told least on the nervous system and on the health of those who were engaged in public assemblies, and one that was, at the same time, the best for the transaction of public business. The light itself should be altogether concealed, or at least very considerably out of the direct line of vision. He would only add that light transmitted through ground glass was very offensive to some, and that a smoother and opalescent material gave it a softness of tone that could never be commanded by the ground glass. Light radiated from invisible burners, and, falling upon convex plaster of Paris surfaces and solid flowers made of the same materials, and tinged to any agreeable tone, gave a very pleasing and diffused radiation, with which any desirable amount of illumination could be obtained for public buildings.

SEVENTH LECTURE.

In this lecture Dr. Reid commenced with an explanation of the manner in which fire-proofing interfered with the ventilation of some public buildings, and the method of obviating the defects arising from this source. The whole question of fire-proofing required revision. An examination of the construction of different buildings said to be fire-proof would exhibit a great diversity in the standard aimed at, and in the amount of security given against fire. Ventilation required the ingress and the egress of air. Some systems of fire-proofing contemplated the entire prevention of such movements when not in actual occupation, and therefore valves (doubled, if necessary, for additional security) were requisite to cut off all communication with the air flues. The importance of separating contiguous rooms or buildings by fire-proof walls and floors was universally recognized. But the great point desirable in public buildings was to use no combustible materials, or a portion so small that even if on fire it could not do any material injury. These also could be charged with chemicals of different kinds, so as to diminish their ready accendibility. Various experiments were then made illustrative of the action of alkaline and earthy salts in preventing or retarding the combustion of wood, cloth, and other inflammable substances used in building or for furniture. Many fires originated not merely from carelessness, but from an ignorance of the first principles of chemistry. In the present state of society, in which the extension of art and science had introduced the use of so many new materials, it was essential that the chemistry of daily life should be made an elementary branch of general education.

A number of special facts were then mentioned in illustration of this position. It would give increased power and facility in conducting operations of art, and in dealing with combustible and explosive materials. To illustrate this, a portion of gunpowder was placed in a small copper cup, and covered with oil of turpentine. The oil of turpentine was then inflamed. It continued to burn above the gunpowder, which was not at first in any way affected by it. The flame was blown out, and rekindled. This was repeated several times in succession. At last the gunpowder was exposed, the level of the burning fluid having descended below the surface of the central portion. Still it did not fire; it was surrounded and enveloped in a vapor of oil rising rapidly from the portion below. At last, the oil being nearly consumed, and the edge of the flame coming in contact with individual grains, they deflurated one by one, and soon afterwards the rest of the gunpowder exploded.

This experiment was then varied by placing a small portion of gunpowder on a flat brick, drenching it with oil of turpentine, and sustaining continually around it a small portion of this fluid. A light was then applied, when the oil alone was kindled; the gunpowder acting as a wick, and remaining totally unaffected so long as there was any oil in the vicinity to be consumed.

It was then argued that general instruction in chemistry would give a similar power of control over many sources of fire, and that the principles he had explained in connexion with this illustration could in many cases be practically applied. It would also lead to the more extended use of fire-proof or incombustible materials in all classes of building, by giving correct views as to their nature and capabilities, and the advantages attending their introduction.

The next subjects were the ventilation of underground mines and of ships. These presented peculiar and somewhat similar difficulties, from the comparative inaccessibility of the lower portions of both to the direct access of atmospheric air.

In the class of mines to which he adverted, the great difficulty lies principally in the expense of making ventilating shafts, particularly where springs of water interrupt their formation, or the presence of fire-damp render it important to have a larger amount of ventilation than would otherwise be requisite. Nothing would contribute so much to the better ventilation of mines as the invention of machinery and apparatus for facilitating the sinking of shafts. The attention of men of science and practical engineers should be directed specially to this subject. Hitherto he had not had the opportunity of visiting mines in this country, but he had examined many mines in Great Britain, more especially in the northern mining district, on which he had reported officially when acting on a commission of health for cities and populous districts in England and Wales. In some of the most dangerous mines in England a very slight interruption to the ventilation, or a fall of the barometer, causing a rapid discharge of fire-damp from the coal, greatly increased the risk of explosion. Hundreds were at times subjected to the most horrible deaths, the mixture of fire-damp and air in numerous mines constituting, at the moment of explosion, a kind of aerial gunpowder that equally surrounded the body and penetrated to the interior of the chest. In no range of cases where ventilation was an absolute necessity would education in science do more good than in the mining districts. It was not enough to have a few able superintendents here and there. Every mine and every district of a mine ought to be much more frequently examined and reported on than was customary at present. He had found in some cases, even recently, that the fresh air intended for the supply of a pit, where there were hundreds of men at work, was contaminated largely when the wind blew in a particular direction from a large heap of waste fuel of inferior quality that had been burning there for many previous years. He mentioned this merely as one of the numerous instances which could be pointed out of the impossibility of checking evils of great magnitude, where more intelligence did not prevail in respect to the nature of the materials which were employed.

One of the shafts of access to the pit, or mine, was usually converted into a ventilating flue, by kindling a large fire, not at the bottom of the pit, but at one side, near the bottom. From this a large flue conveyed the vitiated air and products of combustion to the shaft, at a sufficient distance above the lower part to permit them to cool on the way to a degree which would allow men and materials to pass safely up and down the shaft. Dangerous atmospheres were sometimes diluted with air, by proportionate ventilation, so as to take away all risk of explosion; or discharged by a separate shaft, or by a separate channel, into the ordinary ventilating shaft, far above the fire, so as to prevent their coming in contact with flame. Mechanical appliances were used in some mines to promote ventilation, and advantage had also been taken in different places of the steam jet. Choke damp (carbonic acid) infested numerous mines, and was frequently a cause of death. The Davy lamp, though an invaluable invention, was not always to be trusted, even with all the improvements that had been suggested in recent times. An infinitesimally small particle of carbon might be projected, sufficiently hot from the flame of the lamp, through the wire gauze, by a sudden commotion of the air arising from the falling in of any portion of the roof of a mine, or any other cause, and be fanned into an active combustion in an explosive atmosphere, though ordinary flame is entirely arrested by the wire gauze proposed by Davy.

Again, in many mines, partitions of wood giving way, from the decay of the material, rendered the ventilation less effective; and, in short, from the length of the air courses, extending sometimes to ten, twenty, or thirty miles, the underground miner almost always worked in an atmosphere more or less contaminated; and he did not consider that sufficient exertions were made at present, either by the extended application of practical science, or by the education of the miner, to place this subject on the footing demanded both by the dictates of humanity and by a true economy as a matter of business.

The ventilation of ships had made less satisfactory progress, probably, than that of any other cases in which ventilation was so important. From the time of Dr. Hales, who had long since entered on this question practically, with great ability, and at a period when much of the information now made accessible by more modern chemistry was not available, it had at different periods been taken up, and again neglected; and even in his own experience he had seen it alternately prosecuted with vigor, and abandoned by successive directors of the same board, according as their appreciation or want of information as to the laws of health had dictated. The sea had had its "black holes of Calcutta" as well as the land. In some cases almost every individual confined under deck, in a storm, had been literally suffocated in consequence of the want of fresh air. Even a very few years ago a case of this kind had occurred in the Irish channel. Still more recently hundreds of Chinese had perished on board ship from the same cause. During the late Crimean war, the suffering and death on shipboard, during a storm in the Black Sea, had been extreme. In one of the most crowded vessels, where defective ventilation added its horrors to disease, nearly a hundred perished in a single night. How often was it forgotten that a very small cause would put out the feeble flame of life, when it had to struggle at the same time against disease and against a vitiated atmosphere, poisoning the very fountain at which it should be renewed at the rate of twelve hundred respirations every hour. If it had been right in him to advocate the cause of general education in the elements of science in speaking of other cases where ventilation was necessary, it was still more essential that it should not be forgotten as a means of promoting the purity of the air of ships.

On examining the condition of ships-of-war, packets and merchant vessels, when his attention was first specially directed to this department, he had not met with a single case in which any arrangements had been made beyond the windsail, and occasionally a few copper or other tubes, acting locally for the supply or discharge of air, and not generally on the whole ship. The effect of these was entirely dependent on the state of the wind. There was no ventilating power that could be put in operation in calm weather, sufficient to meet the contingency of a storm when all side ports and scuttles were closed, and even the very hatches battened down to prevent the ingress of water from the deck. In experiments which he had made on board the Benbow, a seventy-two gun ship, by the kindness of Admiral Houston Stewart, he had used a fanner that sustained a plenum current in a tube made of canvass about four or five feet in diameter. He had afterwards seen a small fanner introduced by Captain Warrington, who had been strongly impressed in a voyage from India with the necessity of the ventilation of ships. But whether fanners, screws, pumps, or any other variety of mechanical power was used for this purpose, a system of tubes or ventilating channels was absolutely essential to admit of a satisfactory effect being insured, particularly on those occasions when ventilation was most imperiously demanded. A ventilating power worked by heat alone was not so generally available on board ship as other means; still, however, it could be used with advantage in many cases when judiciously applied, and the cooking stove could often be rendered useful for this purpose by intelligent officers. In steamboats, the machinery and the fires for the production of steam gave twofold facilities for ventilation. It was inexcusable, therefore, that they should not be more systematically ventilated than they generally were. Any amount of appropriation, almost, could often be secured for the most superb cabin decorations, while a comparatively trifling sum was as often denied for the means of giving the pure breath of life.

A diagram was then shown illustrative of the plans executed by the directions of Dr. Reid in different classes of ships. Those introduced in two of the Queen's yachts were specially mentioned, and that in the Minden, the hospital ship used during the former Chinese war. He referred also to three steamers he had ventilated for an expedition to the Niger. Emigrant ships and packets were then mentioned, and it was strongly urged that were nothing more done than the introduction of a single ventilating tube from stem to stern, a great and important improvement would be secured. By this, with appropriate power apertures, and with valves, vitiated air could be extracted from any part of the ship in the line of the tube.

At the same time he deprecated the idea that this should be the only improvement introduced where many were crowded in cabins or small spaces. A ventilating tube should be supplied to every individual cabin or place occupied by passengers, and indeed to every isolated portion or cavity of the ship. And in large vessels, with crowded decks, the officers should be instructed in the best methods of converting the ladder ways and cargo hatches into ventilating shafts in proportion to the numbers present. Nor was it difficult to construct temporary air pumps or fanners to assist in the discharge of vitiated air, though it would be much better to have these made on shore and kept in readiness for use on shipboard.

The important question of quarantine was then introduced and its relation pointed out to the subject under consideration. The want of systematic ventilation in ships and the deficiency of chemical information in respect to the necessity of removing moisture, to a certain extent, at least, from different articles of merchandise, occasioned an annual loss in this country alone that would probably, if he was correctly informed, be counted only by millions if all the circumstances of the case were fully taken into consideration. It was most important that an effective quarantine establishment should be maintained, and that hospitals should be so constructed that all the vitiated air from them should be passed through fire, or so altered, at least, by heat or chemicals, as to prove as unobjectionable as air escaping from an ordinary habitation. The introduction of ventilation that would remove the vitiated air from each patient laboring under a severe form of any disease rendering him liable to quarantine, was peculiarly important in quarantine hospitals. It would contribute not only to the health of the patient and to that of the attendants and of the other patients in the same ward, but would tend very much to relieve those without from all apprehension as to the escape of any dangerous atmosphere from the precincts of the hospital. But it was still more important to the public, to the merchant, and to the sailor, that a right system should be adopted in the shipping of all goods prone to convey disease from an infected port, or develope it during a voyage. He contended that this object would be greatly promoted by simply drying, to a certain extent, before shipping them, special classes of exports, and by the introduction in all ships of a ventilating tube from stem to stern, such as had been explained.

Another important measure that should be adopted at all great mercantile ports consisted in providing a portable ventilating apparatus that could be placed on the deck of any ship arriving in a very bad condition, and capable of destroying all noxious effluvia escaping from it, while maintaining as effective a ventilation as circumstances might permit. It was also strongly urged that a steam-tug should be provided at such ports capable of meeting all extreme cases at once, of discharging vitiated air with a power that would make the effect manifest in a few minutes, and also of applying warm, cold, or a fumigated atmosphere to the whole or any part of the ship.

Finally, a special provision should be made on the quarantine grounds for the reception and purification of all suspected goods which it might be necessary to land or to destroy. Many were the cases of disease on shore that had been traced to materials or goods thrown overboard. By the action of a heating, fumigating, and ventilating apparatus consuming noxious products, much valuable merchandise might soon be restored, and worthless materials consumed without danger.

By these varied arrangements the sick could be at once conveyed on shore to a proper quarantine establishment in a ventilated tug, merchandise purified on board ship or on shore, and the public good secured with the least possible tax on the mercantile interest. It was more peculiarly the province and duty of the merchants themselves to have their goods so shipped and their vessels so ventilated as to reduce to a minimum the chances of loss by detention at quarantine, to say nothing of the claims of humanity; and the public could not look on with apathy, either at the loss of life arising from preventible disease on board ship, or the necessity of incurring extreme expense beyond what was necessary for the most effective quarantine establishment.

In concluding these remarks, Dr. Reid took occasion to notice the general condition of the life of the sailor at sea, the hardships to which he was so often subjected, the magnitude of the interests involved in the right construction, management, and efficiency of ships, and of the practicability of immense improvement in this department, more especially in the mercantile marine of all nations. The diminution of shipwrecks, and the prevention of loss were not the only objects requisite. The service should be put on a better footing; the public should support nautical schools and schools of naval architecture, on the same principle that they recognized the importance of supporting or contributing to the support of other departments of education. It was hard to tell what an extended navy and increased commercial relations might yet accomplish between man and man. And were they to lose sight of the mariner in carrying out such national objects, even if it were possible to attain otherwise the desired result, was he to be neglected, whether he might be the rough sailor before the mast or the accomplished officer, skilled in all that science could apply either in the management of his own ship, or in extending the boundaries of human knowledge? Where had there been recorded, at sea or on shore, any memoir of a man of a more refined sensibility, of more daring intrepidity, or of more heroic devotion, than that which characterized Dr. Kane; the intelligence of whose untimely death had just arrived, and whose name would ever be cherished with admiration, regret, and esteem, on both sides of the Atlantic.

EIGHTH LECTURE.

The eighth and concluding lecture of this course embraced an outline of a series of experiments on acoustics, and a description of the construction for acoustic purposes of different public buildings which had been designed by the lecturer or altered under his direction. After a short exposition of the leading principles of acoustics, it was contended, though there might be no end to the peculiarity of developments arising from the use of new materials, new designs, and new decorations, that these principles were sufficiently well known to guide construction, particularly if accompanied with adequate provisions for the escape of sound, after it had effected the object desired—a point that had not, so far as he was aware, met with adequate attention till some of the experiments had been made which he had described. Without this escape, or an equivalent absorption of sound, which was not compatible with many structures and decorations, sound continued too often to reverberate and interrupt the distinctness of succeeding sounds. He then described rooms in various parts of Europe, where the sound was audible from five to twelve seconds after the cause producing it had ceased to act; and added that in such places, supposing only three syllables to be pronounced in a second, from fifteen to thirty-six successive syllables were constantly ringing in the ear and modifying or destroying the enunciation of every succeeding word.

In general, sound was most beautifully distinct and clear in a wood or on the surface of the ocean, no returning echo or reverberations interfering with the sweetness or purity of each succeeding note. If a room were built of properly absorbing materials, or lined with those that did not reflect sound, any form could be given to it that the architect required. It would not be powerful in sustaining sound, but, with adequate power, there would be no jarring reflections. If parallel reflecting surfaces were largely introduced and great altitude given, dissonant sounds would equally destroy or mar both speech and music. Good effects were attained when the highest power of reflection was given near the ear of the hearer and the voice of the speaker, the sound that had done its duty being then absorbed or discharged. The object was attained in a still higher degree when the reflection permitted was induced by materials that had the power of vibrating independently of the general structure. Dr. Reid then described the peculiarities of the acoustics in his class-room, and the trials made in it by members of government and of Parliament; passing then to the old House of Commons, which he had treated as an acoustic instrument, using glass and pine wood largely in the interior, and combining universal ventilation with the means of escape, both above and below, for the sound that had done its duty. The temporary House of Peers he had treated in a somewhat similar manner, but there essentially he had introduced largely a resilient surface of sheet iron on both sides of the house, immediately opposite the most important benches, where the tone of speaking and hearing required the highest attention. In the new House of Commons a different series of arrangements had been introduced in opposition to his views, but the House had no sooner met and tried it for a few days than they declared it was not fit for the transaction of business with the facility they had been accustomed to in the previous house during the preceding fifteen years; and accordingly the ceiling was lowered in the centre, and on every side, the lateral portions of this new ceiling cutting the windows into two parts, the lower portions solely remaining available to the House. Dr. Reid then entered on a number of other points connected with churches and schools which he had been called upon to alter, sometimes increasing the power of sound by lowering the ceiling and other arrangements, and on other occasions diminishing excessive sound by providing means for its escape or absorption. He then adverted specially to the lecture room of the Smithsonian Institution, and complimented Prof. Henry on the arrangements adopted, saying that it was one of the very few lecture rooms where the voice could be enunciated and heard without effort on the part of the speaker and hearer.

Dr. Reid then adverted to the great progress of acoustics in later years, though it had not yet received the same proportionate attention as optics, and gave a number of illustrations of the effects of the voices of different public speakers, from Wellington and Peel to O'Connell and Shiel; pointing out also the leading peculiarities in the voices of Jenny Lind, Rubini, Catalani, and in the violin of Paganini, which he described as wielding the power of an Orpheus in modern days, and as having exceeded in his opinion rather than fallen short of the almost fabulous terms in which it was often mentioned.

A brief review of the whole question of architecture was then taken, and the necessity shown for combining utility and economy, as well as true beauty and harmony of structure. The great questions of acoustics, lighting, warming, and ventilating might be mutually interwined or accommodated to each other, and perfected with the design and decorations as much as was necessary, before any building was commenced. The principal desiderata necessary for the future progress of architecture were next adverted to; the importance of establishing colleges or special curricula in existing schools for civil and naval architecture, and the immense amount of valuable information and experience at present lost from the want of such establishments were pointed out; universal education in the elements of science was urged as equally important to health, arts, and manufactures, and the extended organization of architectural, agricultural, polytechnic, and industrial institutions.

Dr. Reid then referred to a paper that he had recently published on a college of architecture in the American Journal of Education, edited by the Hon. Henry Barnard, and thanked his audience for the interest they had taken in his exposition of the views he had advocated. He concluded his lectures with the following outline of the course of study recommended for students of architecture:

CURRICULUM, OR COURSE OF STUDY RECOMMENDED FOR STUDENTS OF ARCHITECTURE, BY DR. D. B. REID.

I. GENERAL STUDIES, referring to the materials of which the globe is composed, their power and capabilities, and their relations to the human frame.

1. Chemistry—history of the elements of which the globe is composed, and of their combinations.
2. Mechanical philosophy, including the mutual relations of solids, liquids and gases.
3. Heat, light, electricity, and magnetism.
4. Mineralogy and geology.
5. Meteorology.
6. The general structure and physiology of the frame of man—principles of hygiene.

II. SPECIAL STUDIES.

1. The materials used in building, natural and artificial—their strength and capabilities.
2. The principles and practice of design and construction—the different orders and styles of architecture.
3. Outline of the history of architecture as a fine and as a useful art—the monuments of antiquity—the peculiar works of modern times.
4. Public buildings, including schools, churches, law-courts, prisons, hospitals, theatres, and gymnasia for exercise and recreation.
5. Habitations for the people—extreme importance of the tenement question, and of the right construction of the habitations of the poorer classes in all large cities; its relation to the wants, habits, and morals of the inhabitants.
6. Special buildings for trades, workshops, and manufactories.
7. The construction requisite for acoustics, warming, cooling, lighting, ventilating, fire-proofing, draining and sewerage, the collection and removal of refuse, and the importance of due provision being adjusted for all these purposes before the execution of any building is commenced.
8. The selection of sites for buildings, superficial drainage, the peculiarities required in different classes of foundations.
9. The special architecture required in destroying noxious fumes and exhalations from drains, manufactories, and other houses, and for facilitating the cleansing of large cities and villages, and the general preservation of the public health; the objects and conduct of quarantine on shore.
10. The principles and practice of decorations—the influence of colors.
11. Plans, drawings, and specifications; architectural books required in conducting business accounts.
12. Preparing estimates and measuring executed work.

III. It is presumed that the student will carry on a systematic series of exercises in drawing perspective as well as plan drawing, including isometrical perspective, that he will equally pursue his mathematical studies in relation to every department of the profession which he may have to cultivate, and engage as soon as his time permits, or so adjust his studies as to enable him to become an apprentice to an architect, where he can see daily the realities of his profession. On the whole, however, nothing should be undertaken, if practicable, that will interfere with the right prosecution of his studies.

IV. Lastly, a workshop and laboratory should be provided, in which the student shall have the opportunity of becoming practically acquainted with experimental chemistry, carpentry, and mechanics generally, and be enabled to test materials, and make or direct the construction of models that will facilitate all his labors.